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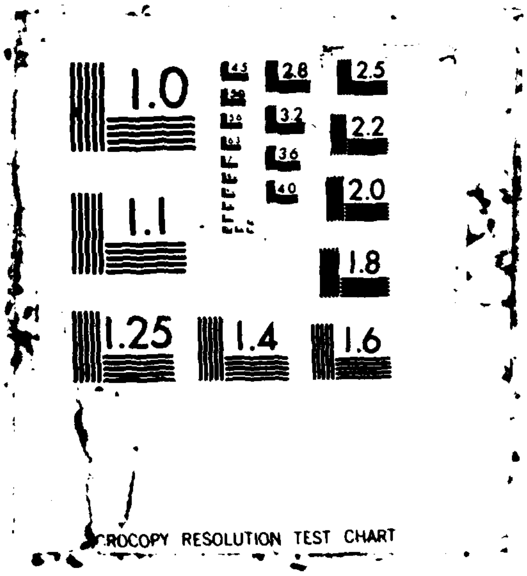
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CROCOPY RESOLUTION TEST CHART

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Extensive simulation and preliminary testing of a monolithic coplanar waveguide (CPW) phase shifter using an optical control technique has been performed. Improvements in numerical techniques has allowed the simulation of non-uniform lossy layers within the substrate supporting the CPW. In addition, a periodically illuminated structure has been proposed, and analysis begun on the slow wave effects expected in such a structure. A CPW transmission line has been fabricated on a AlGaAs/GaAs heterostructure, and initial electrical characterization has begun.

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Monolithic Phase Shifter Study

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D. P. Neikirk and T. Itoh
University of Texas at Austin
Department of Electrical and Computer Engineering
Austin, TX 78712

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Summary

Extensive simulation and preliminary testing of a monolithic coplanar waveguide (CPW) phase shifter using an optical control technique has been performed. Improvements in numerical techniques has allowed the simulation of non-uniform lossy layers within the substrate supporting the CPW. In addition, a periodically illuminated structure has been proposed, and analysis begun on the slow wave effects expected in such a structure. A CPW transmission line has been fabricated on a AlGaAs/GaAs heterostructure, and initial electrical characterization has begun.

Objectives and Status of Research

As discussed in our original proposal "Monolithic Phase Shifter Study", the objective of this work is to model, construct, and test prototype planar waveguide structures that could be used in monolithic millimeter-wave phase shifters. During this period of our research project we have undertaken and accomplished the following tasks:

i) In order to better model the characteristics of coplanar waveguide (CPW) phase shifters, new numerical techniques have been developed to calculate the propagation characteristics of CPW's on substrates with non-uniform dielectric properties transverse to the guide;

ii) Theoretical analysis of wave propagation in a CPW with periodic optically-induced lossy patches has been initiated;

iii) A prototype CPW phase shifter has been fabricated on both a simple semi-insulating and heterostructure substrate, and dc/low frequency testing has been performed; rf testing should begin shortly.

The following discussion presents a summary of work performed during this period, indicating the major points we have addressed.

I) Simulation of CPW Propagation on Non-uniform Substrates

A method based on the finite element algorithm has been developed for the analysis of the effect of laterally localized lossy regions on slow wave propagation in coplanar waveguides. Since in a real optically-controlled CPW we would illuminate through the gaps between the CPW conductors, it might be expected that the mode matching model (which assumed laterally uniform layers) used in the earlier portions of our study might predict performance significantly different from actual devices. This new model allows the dielectric constant and conductivity of the substrate to vary in directions both perpendicular and parallel to the plane of the guide. The method is based on the finite element method but it is extended here to handle a problem involving complex arithmetic. This modification is necessitated by the fact that the structure is essentially lossy and hence the propagation constant is a complex number. Because of this modification, the algorithm developed could not be considered stationary. In the present case, the accuracy of the method has been established by numerically testing for a lossless case.

Once the method was developed, the algorithm was applied to a number of cases. In the earlier trials, we have applied the algorithm for a phase shifter structure in which the doped layer has a uniform conductivity in the lossy layer, generated by optical illumination. The method has now been applied to a structure with a non-uniform lossy GaAs layer (see Figure 1). It was assumed diffusion yields a uniform carrier concentration under the narrow central conductor, but that the concentration fell off by an order of magnitude about 12μm from the illuminated edge under the ground planes. The finite element numerical results showed that such non-uniformity has a little effect on the device performance in a steady state condition. However, time domain results show it does play an important role in analyzing a transient phenomenon.

II) Periodically Illuminated CPW

In the hope of reducing loss, a structure illuminated periodically along the wave propagation direction has also been analyzed. Here, the structure is made of a successive chain of alternating lossy and lossless coplanar waveguides (see Figure 2). The primary objective is to find out if it is possible to create a structure which has a reduced insertion loss and yet retain a slow wave factor of about the same value as the uniformly illuminated structure. If the length of the period is much smaller than the wavelength, the only effect we obtain is a reduced slow wave factor accompanied by a reduced insertion loss. These reductions are in proportion to the duty factor within the period. Presently, we are investigating the case in which the length of the period is approximately one half of the wavelength. It is known that the so-called Bragg reflection occurs in a lossless periodic structure operating near this condition. The analysis being used is a simple cascaded transmission line analysis combined with the spectral domain method for finding the circuit parameters of constituent regions in each period.

III) Fabrication and Testing of a Prototype CPW Phase Shifter

The fabrication of a CPW device (see Figure 3) has recently been completed. At present a lift-off technique is being used, with gold conductors approximately 200nm thick. The guide dimensions are chosen to give a nominal 50Ω impedance when the guide is not illuminated. A constant impedance flare is added to each end of the guide to allow wire bonding to a microwave copper-clad pc board. This board is patterned with another constant impedance CPW flare to allow transitions to SMA connectors. Guides have been fabricated on both a simple semi-insulating substrate and a heterostructure substrate. The semi-insulating substrate device will allow basic calibration measurements to be made. The heterostructure device will allow the generation of the optically-induced electron-hole plasma below the surface of the guide, as discussed in the last progress report. DC testing has been performed, verifying the expected Schottky diode characteristics of the

heterostructure device. Reverse bias leakage current is extremely small, even though the effective areas of the CPW contacts is quite large. Low frequency C-V measurements have also been performed to verify the Schottky diode behavior of the contacts. At present we are preparing the microwave pc board interconnect to our HP 8510 Network Analyzer. For the semi-insulating substrate device, we should have frequency domain data up to 18 GHz shortly. The heterostructure devices need to be fabricated again, due to substrate breakage suffered during processing. We expect heterostructure material grown in the UT Molecular Beam Epitaxy facility to be available in January of 1987.

Conference and Technical Journal Publications

1. "Optically Controlled Coplanar Waveguide Millimeter Wave Phase Shifter," Tenth International Conference on Infrared and Millimeter Waves, p.303, Lake Buena Vista, FL, Dec. 9-13, 1985, (P. Cheung, D. Fun, D. Miller, C.-K.C. Tzuang, D.P. Neikirk, and T. Itoh)

2. "Finite element analysis of slow-wave Schottky printed line," 1986 IEEE MTT-S Microwave Symposium Digest, June 2-4, 1986, Baltimore, MD, (C-K Tzuang, Q. Zhang and T. Itoh).

3. "Finite Element Analysis of Slow Wave Coplanar Waveguide with Localized Depletion Regions," 16th European Microwave Conference, pp. 471-476, Sept. 8-12, 1986, Dublin, Ireland, (C.-K. C. Tzuang and T. Itoh).

4. "Finite Element Analysis of Slow Wave Schottky Contact Printed Lines," IEEE Trans. Microwave Theory and Techniques, Vol. MTT-34, No. 12, December 1986 (C.-K. Tzuang and T. Itoh).

5. "Analysis of an Optically Controlled CPW Phase Shifter Containing Laterally Non-uniform Lossy Layers, Eleventh International Conference on Infrared and Millimeter Waves, Pisa, Italy, Dec., 1986, (C.,-K. Tzuang, P. Cheung, D. P. Neikirk, and T. Itoh).

6. "Picosecond Response of an Optically Controlled Millimeter Wave Phase Shifter," Second Topical Meeting on Picosecond Electronics and Optoelectronics, Jan., 1987, (C.-K. Tzuang, D. Miller, T.-H. Wang, D. P. Neikirk, T. Itoh, P. Williams, and M. Downer).

7. "Finite Element Analysis of Slow-Wave Schottky Contact Printed Lines," Microwave Laboratory Report No. 87-P-2, AFOSR Grant 86-0036, Feb. 16, 1987, (C-K Tzuang, D. P. Neikirk, and T. Itoh).

8. "Optically Controlled Coplanar Waveguide Devices," Int. J. Infrared and Millimeter Waves, to be submitted, March, 1987, (P. Cheung, D. Miller, T. Itoh, D. Neikirk)

Technical Interactions and Oral Presentations at Seminars and Conferences

D.P. Neikirk, "Optically Controlled Coplanar Waveguide Millimeter Wave Phase Shifter," Tenth International Conference on Infrared and Millimeter Waves, Lake Buena Vista, FL, Dec. 9-13, 1985.

D. P. Neikirk, "Exotic Heterojunction Devices for Microwave Circuits," NSF Workshop on Future Research Opportunities in Electromagnetics, Arlington, TX, January 29-31, 1986.

D.P. Neikirk, "Optical Control of a Monolithic Millimeter Phase Shifter," ARO Workshop on Fundamental Issues in Millimeter and Submillimeter Waves, Los Angeles, Ca., Sept. 15-16, 1986.

T. Itoh, presentation at ARO Workshop on Fundamental Issues in Millimeter and Submillimeter Waves, Los Angeles, Ca., Sept. 15-16, 1986.

T. Itoh, presentation at DoD Symposium on Millimeter Wave/Microwave Measurements and Standards, Redstone Arsenal, Huntsville, Alabama, November 6-7, 1986.

Participating Professionals and Advanced Degrees Awarded

Dean P. Neikirk, Assistant Professor, UT Austin
T. Itoh, Professor, UT Austin

C-K Tzuang, UT Austin, PhD awarded: December, 1986, "Slow-wave propagation on monolithic microwave integrated circuits with layered and non-layered structures."

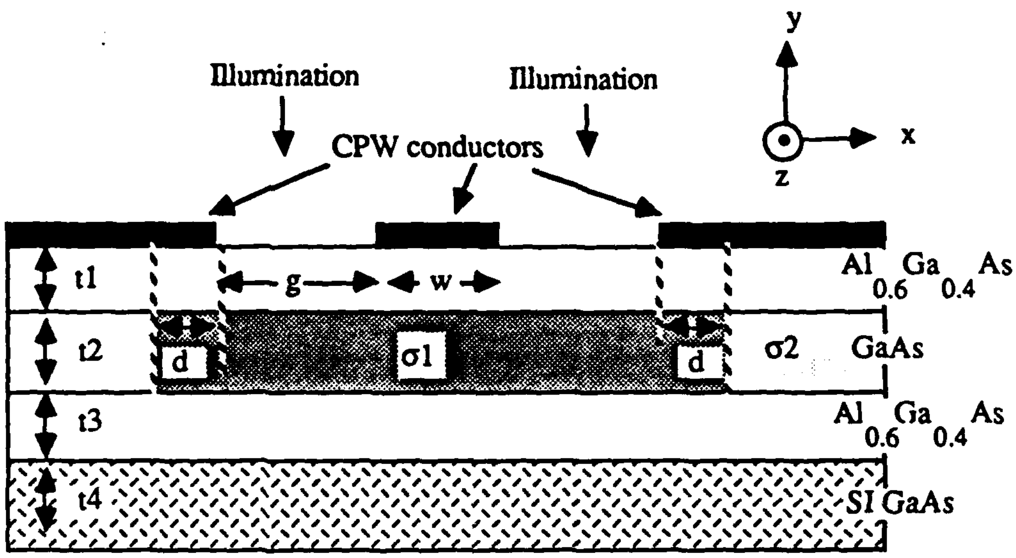


Figure 1: Cross section used to model the nonuniform coplanar waveguide phase shifter; $t1 = 0.1\mu m$; $t2 = 3.2\mu m$; $t3 = 3.4\mu m$; $t4 = 250\mu m$; $d = 12\mu m$; $g = 7\mu m$; $w = 10\mu m$.

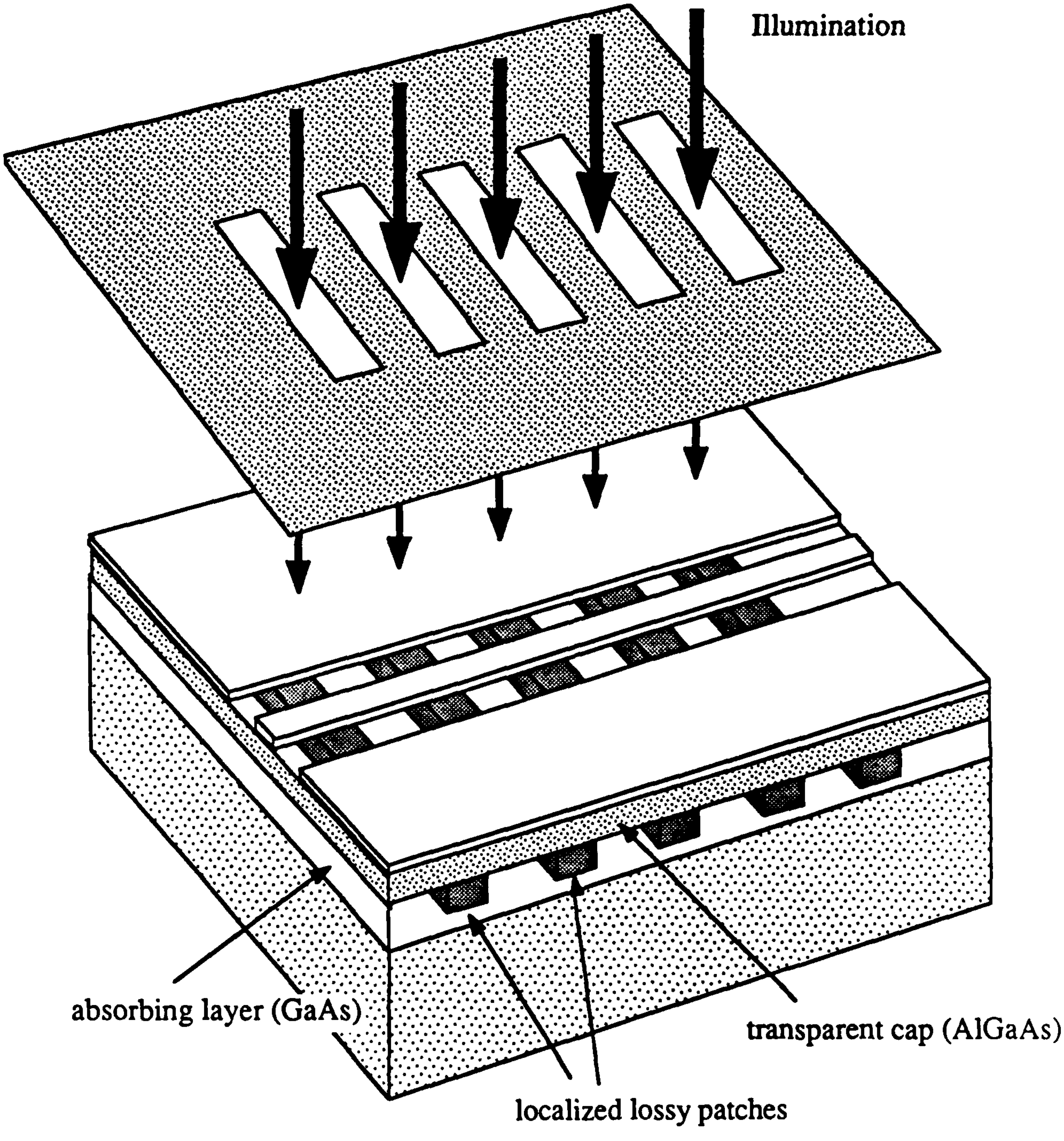
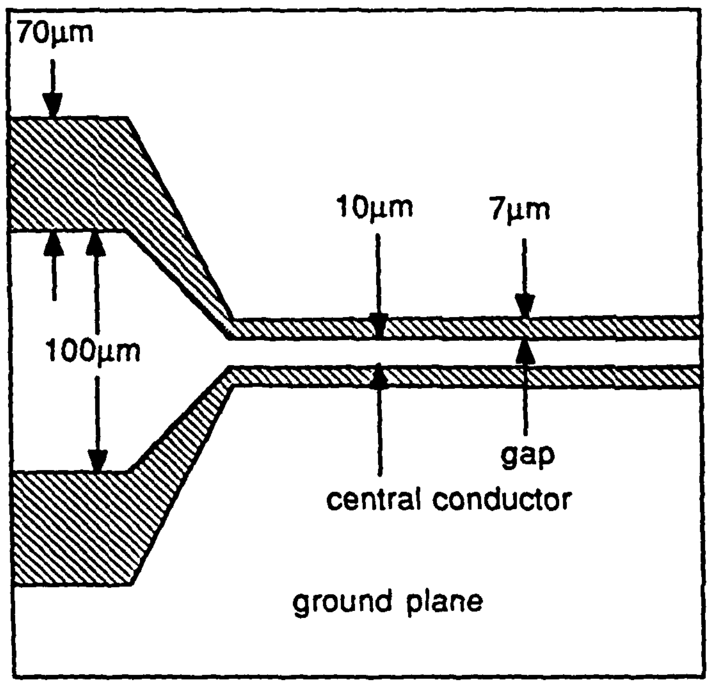
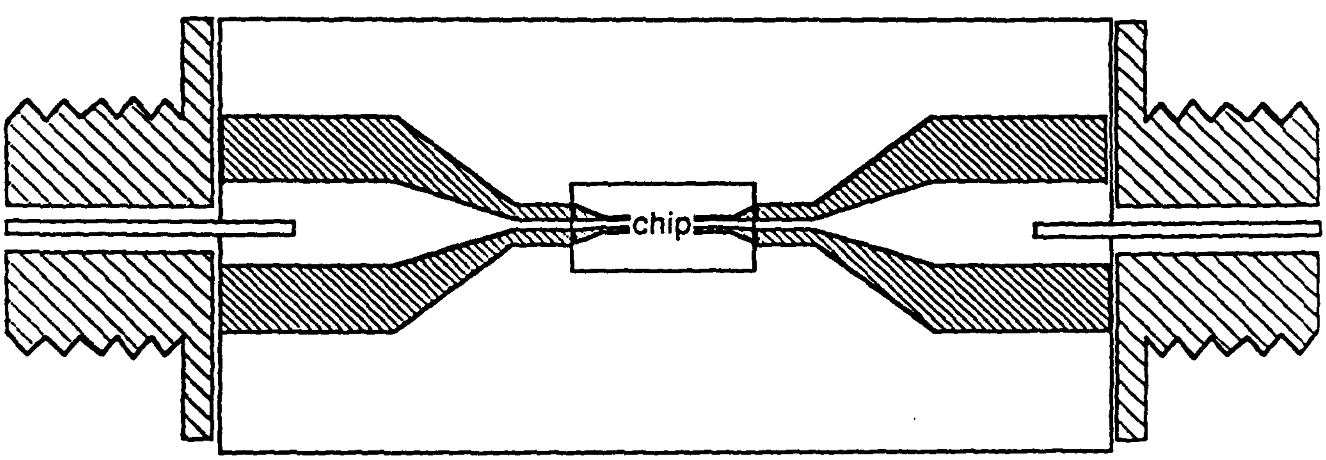

Illumination
absorbing layer (GaAs)
transparent cap (AlGaAs)
localized lossy patches

Figure 2



coplanar waveguide chip detail



test fixture

Figure 3

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